REVERSE ENGINEERING AND SALVAGE ARCHAEOLOGY APPLIED TO UNDERSTAND THE SCIENCE AND TECHNOLOGICAL EXPERTISE USED FOR THE BUILDING OF ROCK-CUT ARCHITECTURE

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Abstract

For revitalizing Indian Knowledge Systems and bridging History and Technology, multi-disciplinary approach is required, where the experts of Science, technology, history, archaeology and languages have to come together, discuss and proceed to redeem lost or slowly getting lost wisdom. While already, the Indian literature has been neglected and relegated to background, about the existing monuments, buildings and structures of both sacred and secular, new myths are created to suppress any research to take place. The study of ancient period of history is treated as sin or useless and thus, emphasis is given to new subjects for survival and job-market. Under the guise of arts, humanities and now they are getting drifted to other social-political subjects. Archaeologists, numismatists, epigraphists, art historians and other related exerts are also getting restricted their research. Under such circumstances, when revitalizing Indian Knowledge Systems and bridging History and Technology are talked about, importace has to be given to reverse engineering and salvage archaeology.

Reverse engineering, Experimental Archaeology and Going back to Traditional Knowledge System:

In recent times, "Reverse engineering" is talked about to understand how a product, goods and artifacts could have been manufactured. It is explained as, Reverse engineering (also known as backwards engineering or back engineering) is a process or method through the application of which one attempts to understand through deductive reasoning how a device, process, system, or piece of software accomplishes a task with very little

(if any) insight into exactly how it does so. In archaeology, "experimental" attempts are made to re-enact, rebuild and recreate old artifacts and monuments. However, it is difficult to understand the science and technology behind the monuments. Unfortunately, without engineering, science and technology background, many archaeologists have been attempting interpret technically, but, they fail miserably, leading to gross misinterpretation. Therefore, for archaeologists, one subject, "Engineering, science and technology required for Archaeology and Archaeologists" should be added in the syllabus. Here, how the rock-cut architecture developed is discussed.

Rock-cut architecture in India: The rock-cut structure found at the Barabar hills are considered to be the earliest rockcut temples found in India, patronized by Asoka for the Ajivikas. However, Vincent Smith dated it to c.500 BCE. Prior to that there was Son Bhandar cave near Rajagriha which is believed to be the earliest and dated back to the 6th century BCE[1]. James Fergusson and

James Burgess in "The Cave Temples of India" complimented the Rock cut caves of western India by stating that if those caves didn't exist, the other cave temples in India wouldn't attract European historians. There are nearly 1200 rock-cut caves in India among them 1000 are located in western India. This region is dominated by the Sahyadri hill ranges. The basalt rock of this region is ideal for carving. Recently, R.K. Singh has analyzed and classified the rock-cut architecture of the Western India with diagrams[2]. The dating of the rock-cut structures was done based on relative method comparing with the script ad hence, there has not been any consensus about the exact dating of them[3].

What is rock-cut architecture?: Rock-cut architecture is the creation of structures, buildings, and sculptures by excavating solid rock where it naturally occurs by scooping out the stock of the material out. Though, different types of drilling, boring, cutting, shaping and related tools were used, as they were not available, the tehnology is doubted. Intensely laborious when using ancient tools and methods, rock-cut architecture was presumably combined with quarrying the rock for use elsewhere. Though, in India and China, the terms cave and cavern are often applied to this form of man-made architecture,

1 **Notes and References**
Sreebama Ghosh, *Rock-cut Architecture in Western Deccan: A Study from Social perspective (2nd century BCE to 9th century CE)*, Viswa Bharati, 2015.

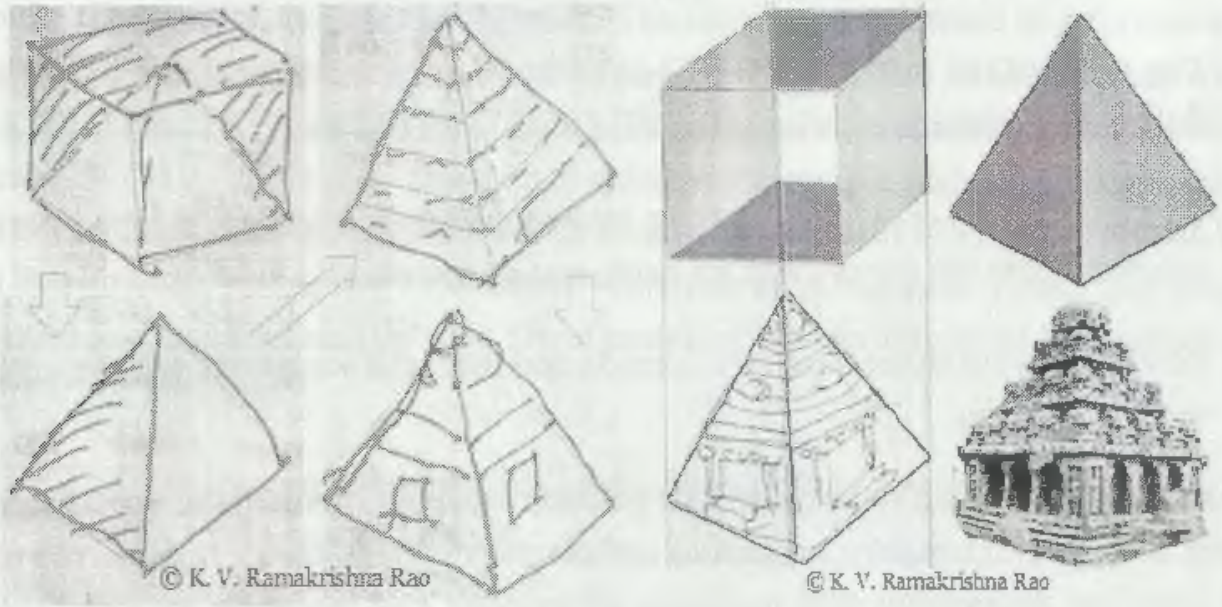
2 Singh, Rajesh Kumar. *Rock-Cut Architecture of Western India - Momentum: Origins of lena cetiyagharas, ca. 120–300s CE*, History Today, No.19, 2018, pp.216-231.

3 The date of Buddha has not been decided internationally, even today. Mahavira and Buddha have been elevated from prehistoric to protohistoric some 70 years ago.

caves and caverns that began in natural form are not considered to be rock-cut architecture even if extensively modified, i.e, worked by artistic man applying all his skills[1].

How rock-cut structure were created with tools?: There have been the formations of rock-cut structure by horizaontal scooping and vertical scooping. The horizontal scooping out rock structure included the modification of existing caves and caverns. The vertical scooping out has been more comlex, as such work has to be carried on from the top to the bottom.

How a rectangular side room is scooped out and formed is shown in the above picture.



How from a cube, step by step temple is scooped out from top to bottom is figurized above. It has been more visualized for understanding in 3-D perspective. Thus, duing the

1 Francis Ching, Mark Jarzombek, Vikramaditya Prakash, *A Global History of Architecture* (Wiley, 2006).

Rastrakuta period, temple-building experts were having such knowledge to create figures and drawings so that the stone-workers, sculptors and and building engineers could work and complete.

The Rock-cut cave temples were built from top to bottom: If one carefully imagines how it could have been done, the technology involved is astounding, perplexing and mysterious.

1. First the architect, stahpati, sculptor or engineer should have prepaed such a plan, sketches, drawings.....in all isometric, orthographic, side view, elevation etc..... and then, excavation, cutting of hillock would have started.

2. This is simply unimaginable, because, that engineer sould have such fantastic visualization, amazing imagination and mental caliber to do so.

3. And the rock-cutters and all sorts of other stone experts and workers too, have had such capabilities to use such tools to cary out their wrk of marking, rough-cutting, drilling, breaking off rock portion etc., so that the whole temple structure could have been accommodated.

4. A rough sketch is shown s to how a cubical stone is taken and cut step-by-step to obtain required monolithic Temple structure.

5. The stock of the material is removed by converting the cube into a voluminous four-sided tetrahedron, triangular solid with square as basis.

6. The tetrahedron is worked cutting into required dimensional stepped parts to accommodate the gopura and its parts, sculptures etc.

7. Rough rock-cut shape structure is made and then, the sculptures could start their work of carving.

Visualizing from top to bottom: The persons involved should have expertise solid geometery, of 2-D, 3-D imagery, properties sedimentary system, rocks, high tensile tools, material handling equipments and hundreds of workers and labourers to carry out the actual work.

How the top to bottom full structure was conceived, imagined and visualized has been the moot question.

Perhaps, from wooden model to stone model in small dimensions, they must have proceeded to design and develop the complete the structure.

By digging or cutting stone stock from the top to bottom and slowly proceeding step by step, the climatic effects were stabilized, controlled and standardized.

As the entire family of the working force was taken care of by the government, they worked peacefully, contributing their whole artistic skills for the betterment of structure.

For example, the Vettuvan koil can be taken. First, three pictures are shown –

1. The plain hilly / mound side view is shown.
2. Rough scooped out portion with proposed structure are shown
3. The final, but unfinished the existing structure is shown.

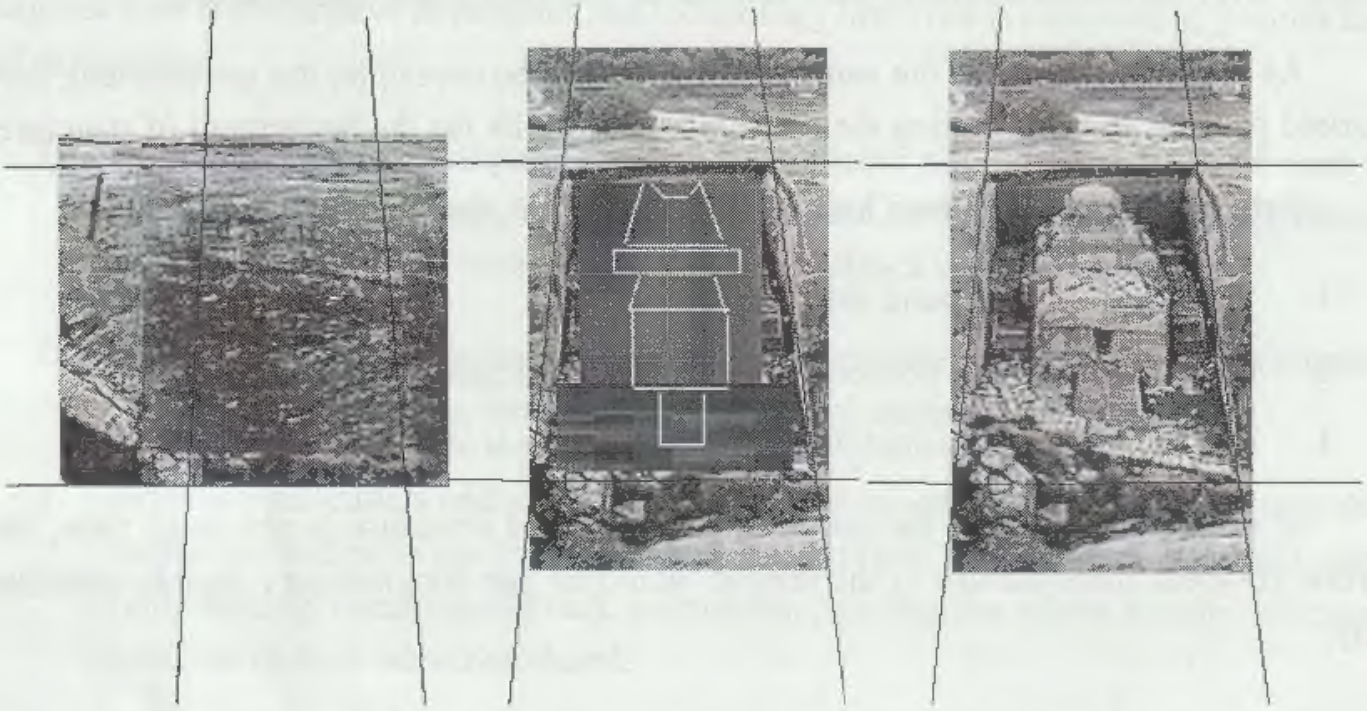
In other words, once, the rough-outer visualized structure is obtained, then, the further rock-cut manufacture of the temple would be just like ordinary temple structure only.

Ellora construction work took 200 years for completion: According to the Archaeological Survey of India, the work at Ellora took 200 years and 10 generations to complete the work of the temple complex. The temple was planned and its construction started under the Rashtrakuta king Dantidurga (735-756 CE) but its major work was done during the reign of Krishna I (756-774 CE). Thus, the work continued thereafter also upto Govinda-IV (930 – 936). The artistic activities of the temple were carried out in several phases. The Lankan king Aggabodhi VIII sent to Govinda III (793-814 CE) two images and a Rashtrakuta inscription celebrates: "Govinda received from Lanka two images of their Lord and then set them up" in a Shiva temple at his capital city of Manyakheta, "like two pillars of his fame."

1. The step by step "scooping out" technology of building of Vettuvan Koil, Tamil-nadu is explained as follows:
2. The site is marked for scooping with all predetermined groundpla and elevaio of the structures contained underneath with instructions how to proceed further.
3. The drawing is sketched on the surface in stages for excavation, clearing off the sides.

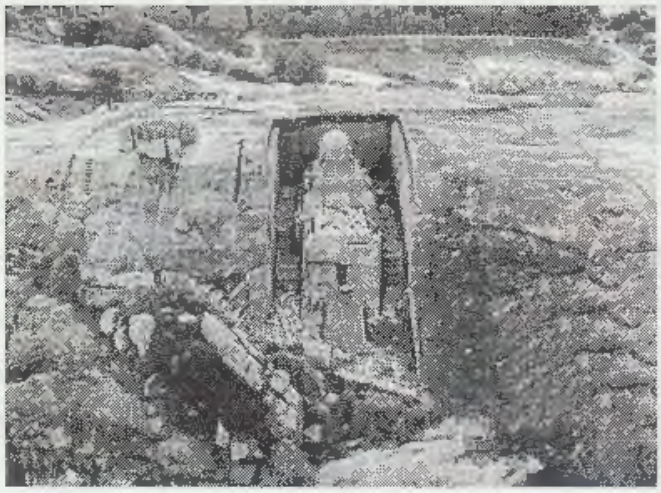
4. Rough structure is excavated with sideways, space and others to accommodate other features.

5. The final one is the completed temple as existing today.

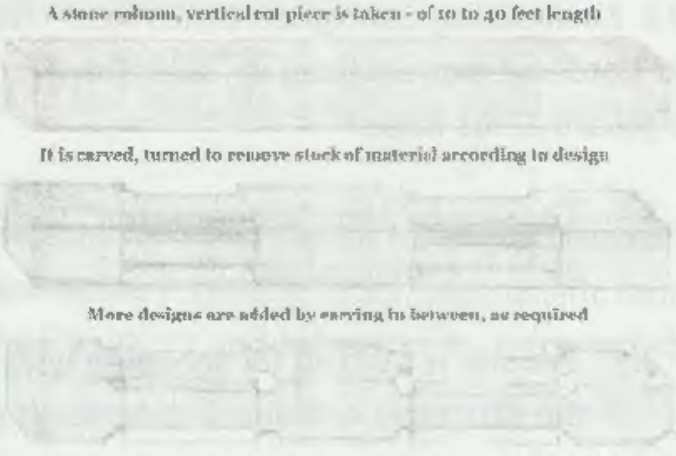


Then, the workers start the actual excavation, cutting etc., and marking area to be excavated, on the surface of the earth.

The following has been the present existing temple



How a pillar is cut, turned carved and manufactued out of a stone column / slab is illustrated here:



While this has been the position of rock-cut architecture, few examples for regular architecture can also be studied in the same perspective.

The manually operated machines used for carrying out different processes of cutting, turning, shaping, polishing etc., of lithic and metallic objects: The pottery and ceramic technology amply prove the existence of rotating wheels, shaping tools, high temperature handling capabilities etc. The bronze and other metallic objects confirm the smelting, melting, casting, forging and other related processes. Just for wood working how hand and leg operated machines were used to turn, remove the stock of the material and shape, for stone working also similar machines were used.

1. The job / work piece is fixed horizontally between the chucks[1].
2. It is rotated horizontally either by leg operated, wheel rotating, and similar system.
3. The tool is held with hand and moved over the rotating surface of the work piece, so that the stock of the material is removed[2].
4. In the case of stones, coolants[3] are used for the easy turning and working reducing heat produced.
5. For different shapes to be produced, different cutting tools are used.
6. Polishing is also done with tools, liquids and other organic materials.
7. Starting with the Indus valley Civilization to modern times, the technology behind the lithic and metallic objects is implied and proven.

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1 A chuck is a specialized type of clamp used to hold an object with radial symmetry, especially a cylinder. In drills and mills it holds the rotating tool whereas in lathes it holds the rotating workpiece. On a lathe the chuck is mounted on the spindle which rotates within the headstock. For some purposes (such as drilling) an additional chuck may be mounted on the non-rotating tailstock.

2 Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helix toolpath by moving more or less linearly while the work piece rotates.

3 Cutting fluid is a type of coolant and lubricant designed specifically for metalworking processes, such as machining and stamping. There are various kinds of cutting fluids, which include oils, oil-water emulsions, pastes, gels, aerosols (mists), and air or other gases. Cutting fluids are made from petroleum *distillates, animal fats, plant oils, water and air, or other raw ingredients. Depending on context and on* which type of cutting fluid is being considered, it may be referred to as cutting fluid, cutting oil, cutting compound, coolant, or lubricant.

How pillars, columns and temples could be manufactured with modern technology has been described by experts[1].

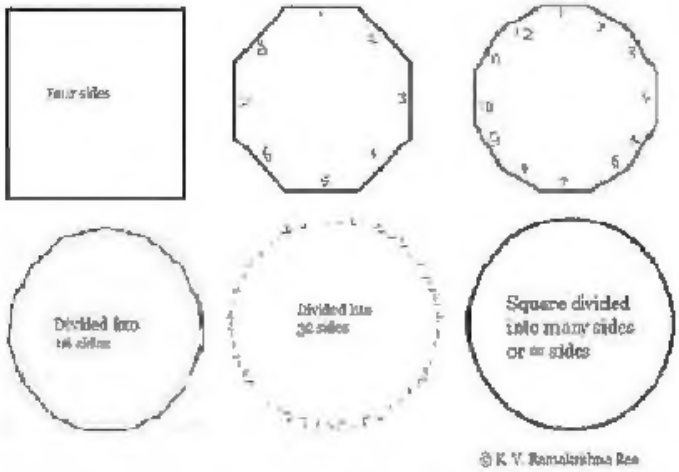
Some researchers have just described the different pillars existing from the ancient to modern periods[2]. Some have attempted to create 3D model, but, not given any manufacturing processes of the pillars[3].

Many companies have started manufacturing, selling and exporting also. That is commercialization has been going on where, the ancient technology is suppressed, distorted and artificially embellished.

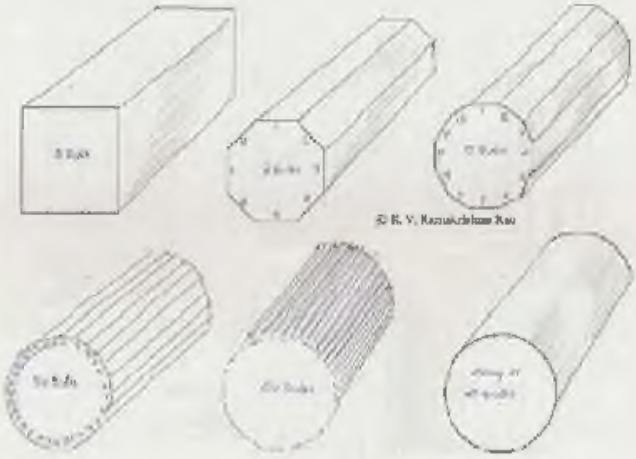
One can see them manufactured at the Ramjanmabhumi Temple factory, Ayodhya step-by-step by workers, of course, using modern tools and equipments.

In the same way, for the Temple to be built at Abu Dhabi, temple pillars, sculptures and parts are manufactured at Rajasthan and Gujarat and exported.

How stone sides are increased to get different shapes - base, as well as sides of the pillars carved



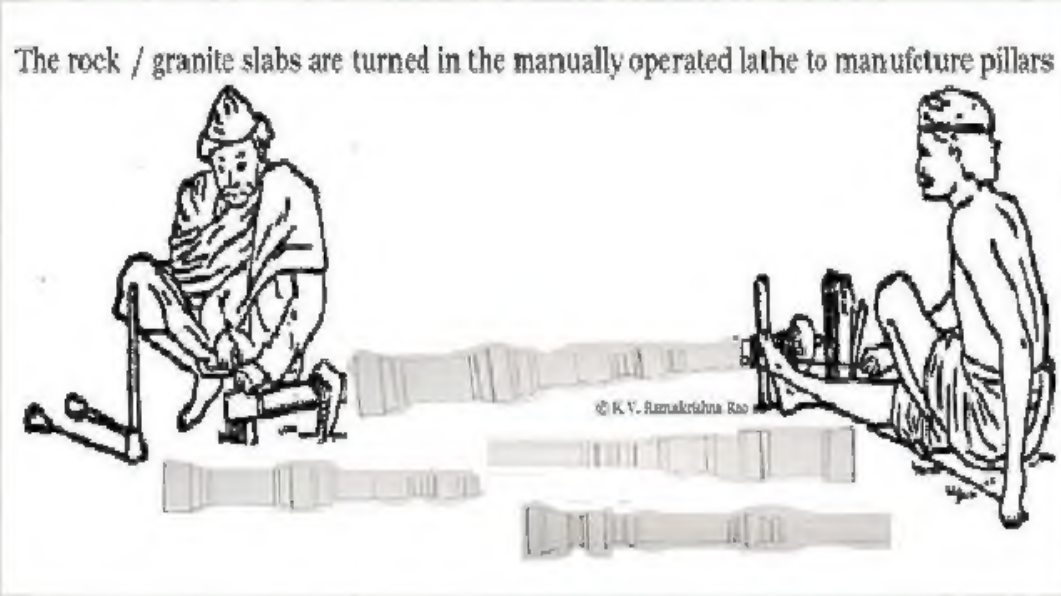
How stone sides are increased to get different shapes - base, as well as sides of the pillars in three dimensions

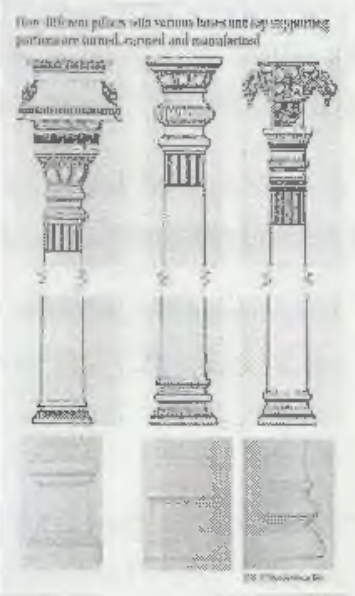


1 Bibhudutta Baral, Divyadarshan C. S. and Manmi Dutta, *Carving of Stone Pillars The Art of Stone Pillar Carving*, http://dsource.in/sites/default/files/resource/carving-stone-pillars/downloads/file/carving-stone-pillars.pdf
Bibhudutta Baral, Divyadarshan C. S. and Manmi Dutta, *Temple Stone Carving -Karnataka Dravidian Art and Architecture*,http://dsource.in/sites/default/files/resource/temple-stone-carving-karnataka/downloads/file/temple-stone-carving-karnataka.pdf

2 Krishnamurthy, S and Tiwary, S Kr, *Origin, Development and Decline of Monolithic Pillars and the Continuity of the Tradition in Polylithic, Non-Lithic and Structural Forms*. Ancient Asia, 7: 1, pp. 1–14, 2016, DOI: http://dx.doi.org/10.5334/aa.78

3 Vishal, Design of Pillars of Temples of India, Department Of Industrial Design, National Institute Of Technology, Rourkela.





Advanced science and technology of the cavemen, but they were "illiterate": Now, researchers have also started interpreting that asterism, or cluster of stars, planetary position, zodiac and such other astronomical concepts were recorded on the stone and rock paintings, thus, taking the prevalence of such knowledge before 3000 BCE or even millions of years back. But, question arises as to why the cavemen or lithic people could not have progressed quickly instead of having a gap of millions of years. Similarly, the lithic men had taken 2000 to 3000 years to become "historical," to invent a script to write and create a "written document." Here also, if such script or signs are not readable by modern men, they were dubbed[1] as "illiterate" or their period "proto-historic." Therefore, historians have to solve these riddles.

Conclusion: In the changing times, many factors of the past are forgotten slowly due to so many reasons. Even, just-past of 50-100-150 years are forgotten just like that. Children are not able to remember and tell the names of their grandfathers and mothers. Under such circumstances, revitalizing Indian Knowledge Systems and bridging History and Technology are discussed about. Definitely, the issues and programmes behind have been very important and they have to be carried on.

The academics of history and archaeology have to be integrated with other subjects of science and engineering or such subjects should be taught to the students of history and archaeology.

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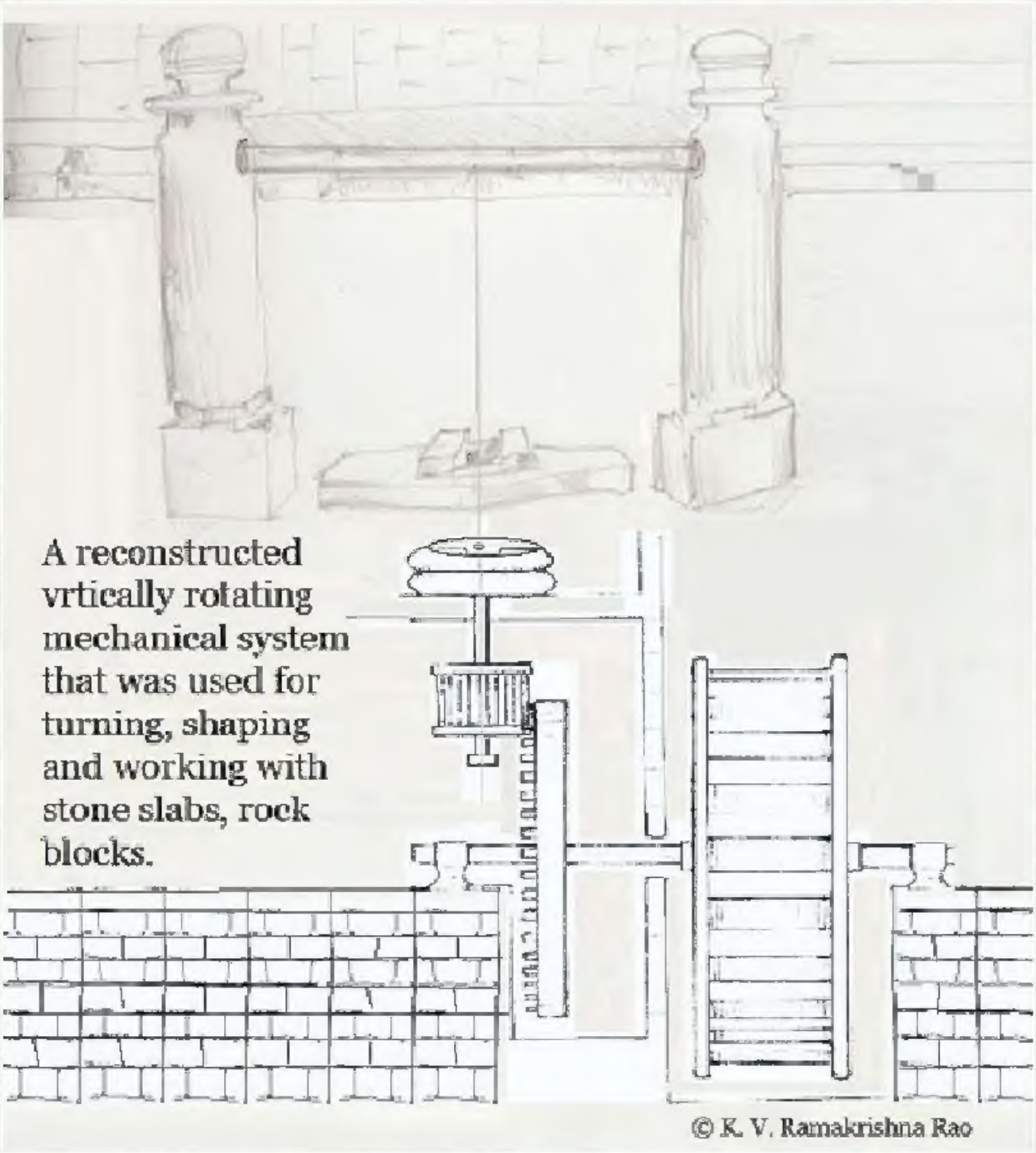
1 Steve Farmer, ***Illiterate Harappans***, http://safarmer.com/washstate.pdf
Farmer, Steve, Richard Sproat, and Michael Witzel. ***The collapse of the Indus-script thesis: The myth of a literate Harappan civilization***, Electronic journal of Vedic studies 11.2, 2004, pp. 19-57.



A reconstructed vrtically rotating mechanical system that was used for turning, shaping and working with stone slabs, rock blocks.

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The study of languages – Sanskrit, Tamil, Arabic, Persian, and other regional languages ae to be revived giving importance, as without which, no original documents can be read, inscriptions read and understood, coins studied and so on.

The history of science and technology of India can be focused on revitalizing Indian Knowledge Systems and bridging History and Technology.